

# High-spin structure of exotic, neutron-rich isotopes studied via $^{208}\text{Pb} + ^{238}\text{U}$ deep-inelastic collisions

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The nuclei around the doubly-closed shell at  $^{208}\text{Pb}$  have long been of interest, both with regard to the shell model behaviour of states in nuclei in the region and because of the presence, and coupling, of collective excitations to these states and the subsequent evolution of collective behaviour as one moves away from the closed shell. While some nuclei in the region can be populated by conventional (HI, $xn$ ) reactions, many, particularly the neutron-rich nuclei, are impossible to reach by these reactions.

Possible ways to populate the interesting neutron-rich nuclei are (i) the fragmentation of heavier isotopes such as  $^{238}\text{U}$ , (ii) fusion with neutron-rich radioactive beams, and (iii) deep-inelastic collisions. In the Pb region, relativistic fragmentation reactions have so far only been used for the observation of delayed gamma-rays below isomeric states [1], while the second method requires radioactive beams which have not yet been developed. Deep inelastic collisions have been used with some success to populate nuclei near  $^{208}\text{Pb}$  [2], but the population of very neutron-rich isotopes has so far been limited due to the use of beams with  $A \leq 208$ . We report the observation of new excited states in neutron-rich nuclei produced in deep-inelastic collisions between a pulsed beam ( $\sim 1.65 \mu\text{s}$  separation) of 1400 MeV  $^{208}\text{Pb}$  ions from the ATLAS accelerator at ANL and a 50 mg/cm<sup>2</sup>  $^{238}\text{U}$  target. GAMMASPHERE was used for the observation of weak  $\gamma$ -rays, both in- and out-of-beam. The drive of deep-inelastic collisions to equilibrate the  $N/Z$  of the products is well-known [3];

our experiment is the first which uses a beam-target combination which preferentially populates neutron-rich nuclei above  $^{208}\text{Pb}$ .

Considerable effort has been put towards the implementation of a Blue [4] database, in which the entire dataset, including the  $\gamma$ -ray energies, times and angles of detection are stored in an energy-ordered list-mode on computer disk. Using Blue, it is now possible to project coincidence matrices gated in complex ways on an as-needed (interactive) basis, in very short periods of time (currently <30 min). This represents a major advance for data-sets of this type, in which numerous channels with multiple isomeric states are populated with small cross-sections. Various combinations of gates on the  $\gamma$ -ray energies, absolute times and relative time differences between  $\gamma$ -rays, are required to enhance the weakly populated  $\gamma$ -ray sequences.

Early highlights of the analysis include the first observation of high-spin states in  $^{206}\text{Hg}$  (up to  $13\hbar$ ), especially the  $10^+$  isomer due to the  $(\pi h_{11/2})^{-2}$  coupling, as well as the first high-spin states in  $^{237,239,240}\text{U}$  (up to  $30\hbar$ ), including octupole-vibrational bands coupled to both signatures of the ground state band in  $^{237}\text{U}$ . Two papers on these results are in preparation. The focus of further analysis is on neutron-rich nuclei such as  $^{211}\text{Bi}$  and  $^{210,211}\text{Pb}$ .

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